2005 Grand Canyon Long-term Fish Monitoring Colorado River, Diamond Creek to Lake Mead

2005 Annual Report

Submitted to

U.S. Geological Survey
Grand Canyon Monitoring and Research Center

Submitted by

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Grand Canyon Monitoring and Research Center
2255 North Gemini Drive
Flagstaff, Arizona 86001

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INTRODUCTION

The purpose of the 2005 Annual Report for Grand Canyon long-term fish monitoring from Diamond Creek to Pearce Ferry is to provide analysis and discussion of 2005 (Trip ID: GC20050531) and previous monitoring efforts downstream of Diamond Creek. In addition, the 2005 annual report addresses the objectives and sub-objectives of the Diamond Creek to Pearce Ferry fish monitoring program.

The global objectives of the program are to detect changes in fish abundance, distribution, and length structure in the Colorado River between Diamond Creek and Pearce Ferry, and more specifically, to provide information on the distribution, movement, and sources of warm water non-native species that inhabit this portion of the Colorado River ecosystem. This information will be used in combination with other long-term monitoring data to elucidate best management of native and non-native fishes in the Colorado River, Grand Canyon.

In addition to the global objective, the sub-objectives of 2005 sampling efforts below Diamond Creek are to:

- Evaluate the utility of different fish sampling gears for detection of long-term trends in fish abundance, distribution, and movement.
- Evaluate tributaries downstream of Diamond Creek as potential future refugia for native fishes.
- Document presence of native and non-native fishes in selected tributaries downstream of Diamond Creek.

This reach of the Colorado River is an important part of the Grand Canyon ecosystem because it represents a transition zone between the fish community in the Upper Grand Canyon and that of Lake Mead. Invasive fish species introduced into Lake Mead may enter Upper Grand Canyon via this reach, which could have detrimental consequences for the native fish community in Grand Canyon by increasing competition for resources and predation of native fish. Monitoring efforts below Diamond Creek may detect increases in non-native species' abundance and detect the introduction of new exotics before these changes are observed in Upper Grand Canyon. In addition, fish monitoring efforts below Diamond Creek may be able to detect range expansion of native species from Upper Grand Canyon.

Fish monitoring efforts in the lower Colorado River between Diamond Creek and Pearce Ferry have occurred infrequently over the last four decades. The first surveys in this reach of river were conducted in the late 1970s (Carothers and Minckley 1978; Deacon and Baker 1976; McCall 1979). Additionally, quarterly fish surveys occurred from May 1992 through October 1995 as a response to monitoring the effects of interim flows from Glen Canyon Dam (Hualapai Tribe 1995; Leibfried and Zimmerman 1996; Valdez 1992, 1994; Valdez et al. 1995). Thereafter, fish monitoring ceased in this reach of river until the Grand Canyon Monitoring and Research Center (GCMRC) established a long-term fish-monitoring program in 2004.

Fish monitoring below Diamond Creek is a cooperative effort between GCMRC, the U.S. Fish and Wildlife Service (USFWS), the Arizona Game and Fish Department (AGFD), SWCA Environmental Consultants (SWCA), and the Hualapai Department of Natural Resources (HDNR). Two sampling efforts have been completed; the first was conducted in October 2004 (Trip ID: GC20041005, Lauretta et al. 2005), the second was conducted in June 2005 (Trip ID: GC20050531, Van Haverbeke et al. 2005). GCMRC provided logistical support and equipment for the trips, and Humphrey Summit and Support, Inc. (HSS), provided sport boat operators.

METHODS

FIELD METHODS

During trip GC20050531, six nights were spent sampling in the mainstem Colorado River between river mile (RM) 226 (Diamond Creek) and RM 280 (Pearce Ferry). Camp locations were primarily dictated by site availability and are listed in Table 1. Sampling typically occurred within 1.5 miles upstream and downstream of camps. A variety of gear types and sampling methods were used, including electrofishing, angling, trammel netting, hoop netting, long lines, and seining. Additionally, backpack electrofishing surveys were conducted in the tributaries of Spencer, Surprise, and Emery Falls creeks in June 2005.

ELECTROFISHING

AGFD personnel, with the assistance of HDNR, GCMRC, and SWCA personnel and participants, conducted electrofishing surveys between RMs 226 and 276.5 within the mainstem Colorado River. A random number generator, developed by AGFD personnel, was used to determine suggested electrofishing sampling RMs on each side of the river within each river reach for 2005 monitoring efforts. However, given that six nights of sampling has been allotted for monitoring efforts downstream of Diamond Creek, hypersampling (sampling beyond that of stratified random sampling) using a stratified random sampling design has occurred throughout the three river reaches downstream of Diamond Creek over the previous three years. Therefore, sampling locations were primarily dictated by camp availability and logistical constraints. Electrofishing sampling typically occurred within 4 miles upstream and/or downstream of camps. All samples were taken shortly after nightfall (~2000 hours), and typically continued for about four hours each night.

Two 16-ft Achilles inflatable sport boats with 50-horsepower, 4-stroke outboard motors were used to fish both sides of the river within one section per night. Two netters and one boat operator occupied each boat during procedures. Each of the two boats were outfitted with a Coffelt CPS output regulator that applied, on average, 350 volts and 15 amps to a spherical steel anode situated directly in front of the boat. The cathode was an identical spherical ball situated directly behind the boat.

Each sample collected during surveys consisted of a single electrofishing pass, approximately 300 seconds in duration, along the shoreline. With few exceptions, shoreline transects were contiguous. Transect start and stop coordinates were recorded with a Garmin III—a handheld global positioning system (GPS) unit—and RMs were estimated following *The Colorado River in Grand Canyon: A Guide* (Stevens 1983).

ANGLING

AGFD personnel, with the assistance of HDNR, GCMRC, and SWCA personnel and participants, employed a series of experimental angling surveys to test the efficacy of angling in monitoring fish species less susceptible to conventional electrofishing or netting gears (i.e., channel catfish, striped bass, etc.). Randomly and opportunistically selected eddies and/or pools as well as campsites were fished each day; the number of sites fished per day depended on the distance needed to be traveled to the next camp location and/or other logistical constraints (i.e., backpack electrofishing surveys conducted during travel). Angler effort and terminal tackle (size 6 Mustad worm hook), line weight (8-lb test), bait type (earthworm), and set-up (½-oz. egg sinker with swivel set-up as a Carolina rig) were all standardized to minimize bias. Four anglers sampled most sites for 20 minutes per site. At each angling site, species, total length, and angler effort were recorded, and GPS waypoints were taken.

TRAMMEL NETTING

SWCA and USFWS biologists, with the assistance of AGFD, HDNR, and GCMRC personnel and participants, sampled with trammel nets for six nights between RMs 230 and 271. Sampling locations were dictated by electrofishing sampling locations. Because the netting and electrofishing trips were combined downstream of Diamond Creek, sampling needed to be conducted from the same camp. Therefore, if electrofishing surveys were conducted upstream of camp, trammel netting occurred downstream of camp, and vice versa, to ensure that each of the sampling gear types was mutually exclusive. Trammel net sampling typically occurred within 2 miles of the camps. Within the chosen sampling locations, trammel nets were set opportunistically as limited by high water velocity, typically at current separation points where an eddy current and a main current diverge (also known as eddy fences). Each netting boat set 5 trammel nets on opposite sides of the river from each other for a total of 10 samples per night. Nets were initially deployed each day at approximately 1700 to 1800 hours, and fished for three ~2-hour hauls for a total of ~6 hours of effort per net. Two-hour hauls were conducted to help reduce fish stress and injury associated with longer hauls.

Two aluminum-hulled Osprey boats equipped with 50-horsepower, 4-stroke outboard motors were used for trammel netting. During netting procedures, one boat operator and two net and fish handlers occupied each boat. Trammel netting was conducted with trammel nets that measured 22.9 m × 1.8 m × 2.54 cm × 30.48 cm (length × width × mesh × panel mesh). If a trammel net became entangled in debris or was swept against/towards the shoreline, the netters moved or discontinued the trammel net set at their discretion.

HOOP NETTING

SWCA and USFWS biologists, with the assistance of AGFD, HDNR, and GCMRC personnel and participants, sampled with hoop nets for six nights between RMs 230 and 271. Hoop net sampling locations closely coincided with trammel net sampling locations. Within and/or near the location that was chosen for trammel netting, hoop nets were set in suitable locations that were typically defined by low-velocity eddies and pools along the shoreline. Nets were set at depths estimated to be less than 3 m, but deep enough to ensure that nets would not be exposed during fluctuating flows. Hoop nets were set in the afternoon (~1500 to 1630 hours). Each of the two netting boats set 18 hoop nets per day, for a total of 36 samples (18 on each river side) per night. Hoop nets were set overnight and placed in pods of three. Nets used were 0.5 to 0.6 m in diameter, 1.0 m long, and used 6-mm mesh with a single 10-cm throat. Hoop nets were scented with commercial trout food (Aqua-Max). Bait was suspended inside the nets in perforated PVC containers ("bait pipes") that allowed odor to escape but prevented fish from gorging on the bait.

LONG LINES

Long lines were also deployed overnight by the netting crewmembers at each sampling location during 2005 sampling. Each long line consisted of 100 ft of ⅜-inch braided nylon rope, with a weight bag attached to the end. A line with a float was also attached at the end to mark locality. Six hooks were attached to each long line, beginning at 20 ft from shore, and then evenly spaced at 11-ft intervals. Hooks used were two #6 (small), two #4 (medium), and two #20 (large). Each hook was baited with frozen chopped chicken gizzards. Long lines were set in suitable habitat, similar to trammel netting habitat; rested on the substrate; and were generally deployed and pulled in time frames simultaneous with hoop nets (i.e., set at ~1500 to 1700 hours and pulled the next morning).

SEINING

SWCA and USFWS biologists, with the assistance of AGFD, HDNR, and GCMRC personnel and participants, seined suitable habitats opportunistically near campsites and during travel on the GC20050531 trip. Seining efforts were focused on backwaters, tributary mouths, and other suitable habitats within selected tributaries. Seining was conducted with a seine that measured 3.6 m × 1.5 m × 3 mm (width × depth × mesh). Seine haul length, width, and depth were recorded to approximate volume seined. In large backwaters and tributary pools, the length, width, and depth of the habitat were recorded to approximate total habitat area.

BACKPACK ELECTROFISHING

SWCA, AGFD, USFWS, and HDNR personnel conducted backpack electrofishing surveys in Spencer Creek, Surprise, and Emery canyons during 2005 sampling using a Smith-Root LR-24 Backpack Electrofisher. The automatic set-up function was used on the electrofishing unit, and surveys were conducted at ~200 to 300 volts and ~0.7 to 0.9 amps. Two dip netters participated to collect fish. These tributaries are currently being evaluated as potential future refugia for Colorado River native fishes.

FISH HANDLING

The standard fish handling protocol outlined jointly between GCMRC and the cooperating agencies (Ward 2002) was followed, with the caveat that carp were tagged to the left of the dorsal fin with Floy tags instead of Passive Integrated Transponder (PIT) tags and were given a left pelvic fin clip as a secondary marking diagnostic. All Floy tags used on this trip were gray with the letters "USGS" followed by a five-digit number between 09127 and 10449. All fish lengths given in this report are total length (TL).

Mainstem Colorado River water temperature and turbidity measurements were collected each day. Because of failed instrumentation, additional water quality parameters (e.g., conductivity, pH, etc.) were not collected during 2005 sampling. Qualitative notes were taken on habitat characteristics, including substrate, shoreline habitat, vegetation cover, and cut-bank height.

DATA ANALYSIS

The coefficient of variation (CV = standard error catch-per-unit-effort [CPUE]/mean CPUE) was calculated for each gear type and species to determine the level of variation in catch rates in 2005. Gear types with highly variable catch rates and; therefore, high CV values for certain species were assumed not to be useful in estimating changes and trends in relative abundance of those species. A target CV value of 0.10 was established for the monitoring program. This correlates to an ability to detect changes in relative abundance of approximately 75% over five years (TRENDS, Gerrodette 1987, alpha = 0.05, beta = 0.20, 2-tailed test, linear rate of change, CV remains constant with abundance, equal sampling intervals). Furthermore, gear types with CV values greater than 0.20 for a certain species were projected to be ineffective in revealing changes in the relative abundance of less than 280% over five years (TRENDS, Gerrodette 1987, alpha = 0.05, beta = 0.20, 2-tailed test, linear rate of change, CV remains constant with abundance, equal sampling intervals); therefore, these gear types were assumed to not be particularly useful for five-year trend monitoring.

Power analyses were completed using June 2005 Diamond Creek to Pearce Ferry CPUE data in an effort to investigate the utility of different fish sampling gears at various sampling levels for the detection of long-term trends in fish abundance, distribution, and movement. To conduct power analyses, the CPUEs for a given gear type and species were bootstrapped and then resampled to produce a given number of

samples. The resampled data were then rerun for 1,000 trials; next, the mean CPUE and the mean $CV_{\bar{x}}$ of the 1,000 means were used for the power analyses.

The length frequency of each species was calculated as the number of fish per 10-mm TL group; species were split by gear type to show the capture bias of size classes for each gear. The longitudinal distribution of each species was calculated as the number of fish (NF)/RM.

All PIT-tag recaptures during the 2005 Diamond Creek to Pearce Ferry fish monitoring efforts were investigated for previous tag histories to provide useful information on fish growth and/or movements.

RESULTS

A summary of the sampling effort within each geomorphic reach is given in Table 2 for 2004 and 2005. Three additional gear types were used during 2005 sampling: angling, long lines, and backpack electrofishing. A limited number of angling samples were taken in 2004, although sampling occurred opportunistically to test the feasibility of using this gear, and methods were not standardized until 2005 sampling.

Fish captures for each gear type are shown in Table 3. Including all gear types, a total of 687 fish was captured in 2005. Red shiner was the predominant species captured by electrofishing (31% of the total catch [TC]), followed by flannelmouth sucker (22% TC), striped bass (16% TC), speckled dace (12.5% TC), carp (11.5% TC), channel catfish (3% TC), fathead minnow (2% TC), and smallmouth bass (1% TC). Angling efforts produced mainly channel catfish (91% TC); however, a few carp (5.5% TC) and striped bass (3.5% TC) were also angled. Trammel netting produced mostly non-native species, including carp (46% TC), channel catfish (37% TC), striped bass (9% TC), and threadfin shad (2% TC). Flannelmouth sucker was the only native species captured in trammel nets, accounting for 6% TC. Hoop nets were the only gear type that captured native species in greater numbers than non-native species, with TC composed of speckled dace (30%), flannelmouth sucker (27%), carp (12%), striped bass (9%), red shiner (9%), channel catfish (3%), fathead minnow (3%), and smallmouth bass (3%). In addition, one young-of-year (YOY) humpback chub was captured in a hoop net at RM 239.6 along a talus shoreline. A total of six species was captured in seines, including red shiner (67% TC), flannelmouth sucker (22% TC), speckled dace (4% TC), striped bass (2% TC), humpback chub (2% TC), and fathead minnow (2% TC). A total of three YOY humpback chub was seined within a backwater at RM 239.5. Long lines produced the fewest number of species of all gears; channel catfish (75% TC) and striped bass (25% TC) were the only species captured.

The results of backpack electrofishing efforts are presented separately for each tributary. In Spencer Creek, speckled dace was the predominant species captured (66% TC), followed by carp (15% TC), red shiner (13% TC), and channel catfish (6% TC). Fish species captured in the mouth of Surprise Creek included red shiner (41% TC), flannelmouth sucker (30% TC), speckled dace (19% TC), and carp (11% TC). Additional sampling efforts in Surprise Creek, farther upstream from the mouth, resulted in the observation of many adult carp and red shiner, but high conductivity presumably prevented captures (D. Ward, AGFD, personal communication 2005). In Emery Falls Creek, fish captures were 100% non-native, consisting of eight mosquitofish. These fish were all captured in the plunge pool at the base of the waterfall and in the creek downstream of the pool. Numerous additional mosquitofish were observed but not captured.

The CV values are summarized by species for each gear type in Table 4. For channel catfish, the sampling method in the mainstem with the lowest variation in catch rates was angling (CV = 0.18).

Carp, fathead minnow, flannelmouth sucker, red shiner, smallmouth bass, speckled dace, and striped bass were most effectively sampled by electrofishing (CVs = 0.19, 0.40, 0.24, 0.14, 0.57, 0.19, and 0.16, respectively). Humpback chub were only captured in seine (CV = 0.77) and hoop net (CV = 1.0) samples. Mosquitofish were only captured by backpack shocking within Emery Falls Creek (CV = 1.0). Threadfin shad were only present in trammel net samples (CV = 1.0).

Power analyses were completed for the most common species captured by three sampling methods: electrofishing, trammel netting, and hoop netting (Figure 1). At the current level of electrofishing effort (170 samples), red shiner, carp, and striped bass estimated CV values ranged between 0.10 and 0.20, and the flannelmouth sucker CV value was estimated to be greater than 0.20. Doubling the electrofishing effort (340 samples) lowers the estimated CV values for all species to less than 0.20; however, values would remain greater than 0.10. At the current trammel netting effort (55 samples), estimated CV values are greater than 0.30 for all species except channel catfish. At least three times the amount of effort would be required to achieve projected CV values between 0.10 and 0.20 for channel catfish and carp. Hoop net analyses suggest that at least three times the current effort level would be required to achieve CV values between 0.10 and 0.20 for speckled dace and flannelmouth sucker. Power analyses were not completed for angling, seining, long lines, or backpack electrofishing.

Length frequency distributions by species and gear type are given in Figure 2. Channel catfish ranged between 130 and 610 mm TL, with the majority between 150 and 390 mm. Carp ranged between 150 and 620 mm TL, with the majority of individuals between 260 and 580 mm. The relatively few fathead minnow captured ranged between 30 and 80 mm TL. The majority of flannelmouth suckers captured were YOY ranging between 10 and 120 mm TL; a juvenile cohort was observed between 120 and 390 mm TL. No adult flannelmouth suckers greater than 400 mm TL were captured during 2005 sampling. The four YOY humpback chub captured measured 60 to 70 mm TL. All mosquitofish captured were less than 60 mm TL. Red shiner ranged between 10 and 90 mm TL, with the majority between 40 and 70 mm. The three smallmouth bass captured were 70 to 80 mm TL. Speckled dace ranged between 20 and 90 mm TL. Striped bass were captured over a range of size classes, from 110 to 520 mm, with the majority between 120 and 200 mm TL.

The capture locations of each species are presented in Figure 3. Channel catfish, carp, flannelmouth sucker, speckled dace, and striped bass were captured within each reach sampled. Fathead minnow were infrequently captured between RMs 246 and 262. A total of four humpback chub was captured at RM 239: three were captured within a backwater, and one was captured in a hoop net along a talus slope. Red shiners were captured in relatively high numbers in every reach sampled, with the exception of the first reach (RMs 225 to 235). A total of four smallmouth bass was captured at RMs 244, 246, 257, and 260. One threadfin shad was captured at RM 260.

A summary of angling catch rates of channel catfish is given in Figure 4. An increase in catch rates of channel catfish was observed below Lava Falls (RM 179) compared with samples taken upstream. Additionally, catch rates were greatest for samples below Diamond Creek (RM 226).

DISCUSSION

Extremely turbid conditions (greater than 13,000 nephelometric turbidity units [NTUs]) during the first sampling effort of the long-term monitoring program below Diamond Creek in October 2004 may have impacted the capture efficiency of several gear types, and researchers involved in the program concluded that data obtained during that sampling effort likely did not accurately represent the real distribution or relative abundance of fish in the reaches below Diamond Creek. It was decided that sampling during late spring would create a more consistent baseline from year to year due to the lower likelihood of major flooding events within the basin. The 2005 sampling effort was therefore moved up from October 2005

to June 2005 in an attempt to sample during non-turbid conditions, which are more representative of the typical state of the river. Sampling conditions during June 2005 proved to be more desirable for both electrofishing and netting due to the low turbidity of the mainstem, the greater ability to capture fish during electrofishing, and the improved ability to set nets in desired habitats.

Monitoring efforts upriver of Diamond Creek rely on CPUE as an index to detect changes in the relative abundance of fish. The ability to estimate changes in the relative abundance of species and therefore to make inferences regarding population trends is related to the variation of the catch rates. Sampling strategies have been designed to detect a 20% change in CPUE over a five-year period for native and non-native species. A CV of 0.1 is necessary for this level of detection; however, sampling efforts in 2005 were unable to achieve this target for any species or gear type.

The methods employed during the trip were evaluated by comparing the catch rates and variances for each species and gear type. The CV for each species was compared across gear types (see Table 4), and the gear type with the lowest CV was assumed to have the greatest ability to estimate species' relative abundance and to monitor trends in the population. Electrofishing was the most effective method of sampling for the majority of species captured, including carp, fathead minnow, flannelmouth sucker, red shiner, smallmouth bass, speckled dace, and striped bass. Angling proved to be the most effective gear type for monitoring channel catfish. Hoop netting and seining were the only sampling methods that detected the presence of humpback chub; trammel netting was the only method that captured threadfin shad; and backpack electrofishing was the only method that detected the presence of mosquitofish. Long lines captured channel catfish and striped bass; however, comparison of variances indicates that angling is a much more effective method of monitoring channel catfish, and long lines are the least effective method of monitoring striped bass.

Power analyses were completed for several of the most common species captured by electrofishing, trammel netting, and hoop netting (see Figure 1) to assess the change in variance associated with increased sample sizes. These analyses indicate that current monitoring efforts are the most effective in monitoring carp, red shiner, and striped bass with electrofishing; however, current monitoring efforts are not likely to be able to estimate yearly changes in relative abundance with enough precision to assess the impact of management actions on the fish community in this reach of Grand Canyon. Similarly, analyses of hoop and trammel netting data suggest that current monitoring efforts will not achieve target variance levels for any species. No power analysis was completed for seining because the sample size is limited by the number of backwaters present. No power analysis was conducted for angling since the angling effort is limited by sampling opportunistically while traveling downstream, and increased effort would impact the ability to sample with other gear types at designated sites. Furthermore, the current angling effort produced a relatively low variance for channel catfish (CV = 0.18), which indicates that this method may be suitable for monitoring this species at current effort levels. A power analysis was not completed for backpack electrofishing because sampling with this gear type occurs opportunistically during travel between study sites. An analysis of long lines was not completed since other methods are shown to be more effective in monitoring species captured with this gear type.

Sampling during 2005 established an initial baseline of the species composition, age structure, and distribution of native and non-native species (see Figures 2 and 3, Table 3). A comparison of the fish community present in 2005 with historical capture information gives some interesting insight into the changes of the fish community over the last decade. During sampling trips from 1992 to 1995, Valdez et al. (1995) noted a dramatic change in the ichthyofauna downstream of Bridge Canyon (RM 235). Numbers of species increased from 9 to 20 below Bridge Canyon, and densities of non-native species increased dramatically. Included in the species captured below Bridge Canyon were black crappie, black bullhead, bluegill, green sunfish, largemouth bass, walleye, plains killifish, and golden shiner, with bluegill and largemouth bass captures being particularly high in fall 1992. None of these species were

identified during 2004 or 2005. Furthermore, smallmouth bass, a species not observed during the 1990s, was captured during 2005 sampling. Additionally, captures of fathead minnow, red shiner, and threadfin shad were noticeably higher during most of the 1990s sampling, particularly in fall 1992. Finally, the presence of age-0 flannelmouth sucker inhabiting mainstem habitat appears to have increased compared with studies during the 1990s.

Habitat characteristics in the Diamond Creek to Pearce Ferry reach were assessed. Because the elevation of Lake Mead has dropped over the past decade, aquatic habitat conditions have undergone extensive changes. In previous years, low-gradient, braided channels characterized the stretch of river from Quartermaster to Dry canyons, with numerous off-channel habitats (e.g., overflow channels, backwaters, etc.) (Valdez 1994). On both the 2004 and 2005 sampling trips, it was observed that the mainstem has undergone extensive downcutting and channelization. This was evident from Separation Canyon downstream, but the effects were particularly dramatic below Quartermaster. Many stands of cottonwood and willow that had previously been close to water level are now stranded several meters above the riverbed, which has been dramatically downcut into alluvial deposits. Some vegetative stands have recolonized at lower levels, while other higher stands have perished, leaving large, dead stands of trees. The river is now characterized in many places by high, collapsing, alluvial cut-banks.

As a result of these hydrological changes, the system has undergone a change from being somewhat lentic to riverine. Rather than river currents' abating near Separation Canyon (RM 240), as they have in former years, strong currents now flow well below Pearce Ferry (RM 280) and continue (albeit in a somewhat abated form) into Iceberg Canyon. A river channel and small rapid are now present near Pearce Ferry, where formerly a wide bay provided access to a boat ramp (now land-locked). The Lake Mead inflow area has shifted from the Pearce Ferry area to below Iceberg Canyon. Currents are channelized and moderately fast to Pearce Ferry and continue until the lake interface at the bottom of Iceberg Canyon. Substrates are largely sandy and limited off-channel habitat exists (only a few small backwaters are present).

Species captured in tributaries included channel catfish, carp, flannelmouth sucker, mosquitofish, red shiner, and speckled dace, with the majority of the catch being composed of speckled dace and red shiner. The presence of YOY native species in the tributaries indicated that these streams might be suitable for native fish rearing. Large-bodied non-native species were observed within Spencer Creek; however, no adult native species were captured or observed within the tributaries.

Species movement cannot be assessed at this time since no fish were recaptured that had been tagged during previous sampling efforts. Sampling efforts in the future are more likely to provide movement data as more fish get marked.

CONCLUSIONS AND RECOMMENDATIONS

Monitoring efforts in Upper Grand Canyon rely on CPUE as an index to detect changes in the relative abundance of fish. Sampling strategies have been designed to detect a 20% change in CPUE over a five-year period for native and non-native species. A CV of 0.1 is necessary for this level of detection; however, sampling efforts in 2005 were unable to achieve this target. Bootstrapping of 2005 data indicates that a minimum of three 6-day trips is necessary to obtain this level of monitoring precision for several non-native species in the Colorado River below Diamond Creek. Current sampling efforts provide no information on the abundance of fish captured downriver of Diamond Creek because the relationship between CPUE and fish species abundance below Diamond Creek has not been defined. However, effort similar to that in 2004 and 2005 may be adequate to monitor distribution of species that are vulnerable to the gear types.

It is recommended that sampling below Diamond Creek continue annually during late spring in order to standardize the sampling effort during a time of year when the likelihood of flooding events is low. Electrofishing, angling, trammel netting, hoop netting, and seining efforts in the mainstem should continue due to the ability of these gear types to capture an array of species and sample a variety of habitats. Long lines proved to be ineffective compared with other gear types that capture the same species. Due to the fact that deployment of long lines is time-consuming and inhibits sampling with other gears, it is recommended that this gear type be eliminated. If long line sampling is continued in future efforts, it is recommended that an additional crewmember be added to the trip. Backpack electrofishing within tributaries should continue to occur opportunistically to assess the suitability of these tributaries as refugia for native species.

At this time, it is not recommended that additional monitoring trips be conducted in an attempt to achieve relative abundance estimates of native and non-native species; rather, other methods of estimating fish abundance should be examined. Recent discussions of warm-water non-native species' control efforts at the 2005 GCMRC Warm-Water Nonnative Fisheries Initiative Workshop included the introduction of new methods, such as radiotelemetry tagging, that may assess habitat use, movement, distribution, and abundance of warm-water species of concern. It is believed that these efforts could coincide with current monitoring efforts to address key sampling method issues, such as gear capture efficiency. Identifying a correlation between catch rates and capture efficiencies may allow for the estimation of species' abundance, and this effort could occur while other valuable information on warm-water species is gained.

Lastly, it is recommended that collaboration with other agencies responsible for fish monitoring within Lake Mead be initiated to acquire data that may be valuable for estimating fish movement into the Colorado River ecosystem from Lake Mead, as well as to provide some insight into the movement of native species from the Colorado River into Lake Mead.

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FIGURES

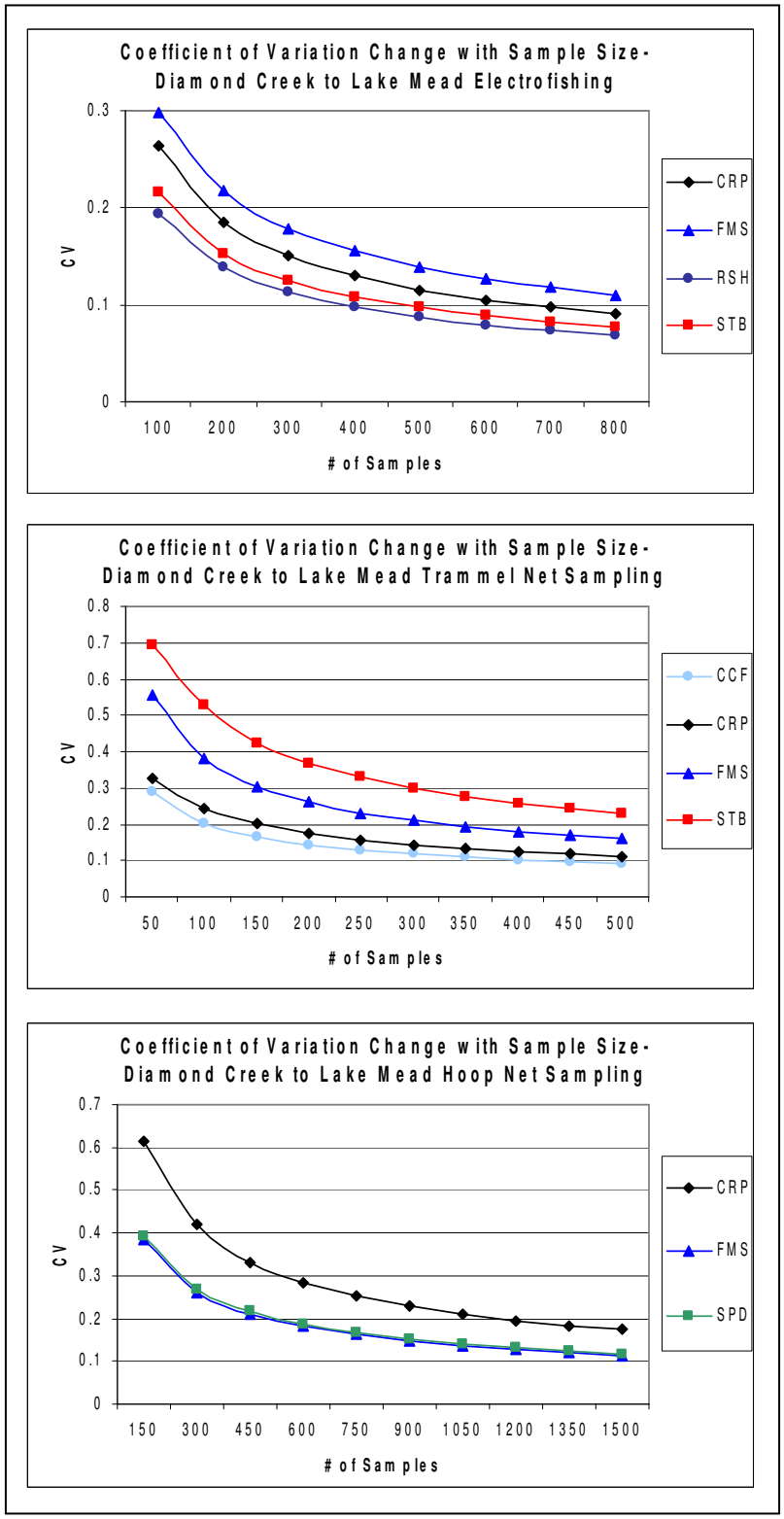

Figure 1. Coefficient of variation changes with sample size based on data from the June 2005 Diamond Creek to Pearce Ferry fish survey trip.

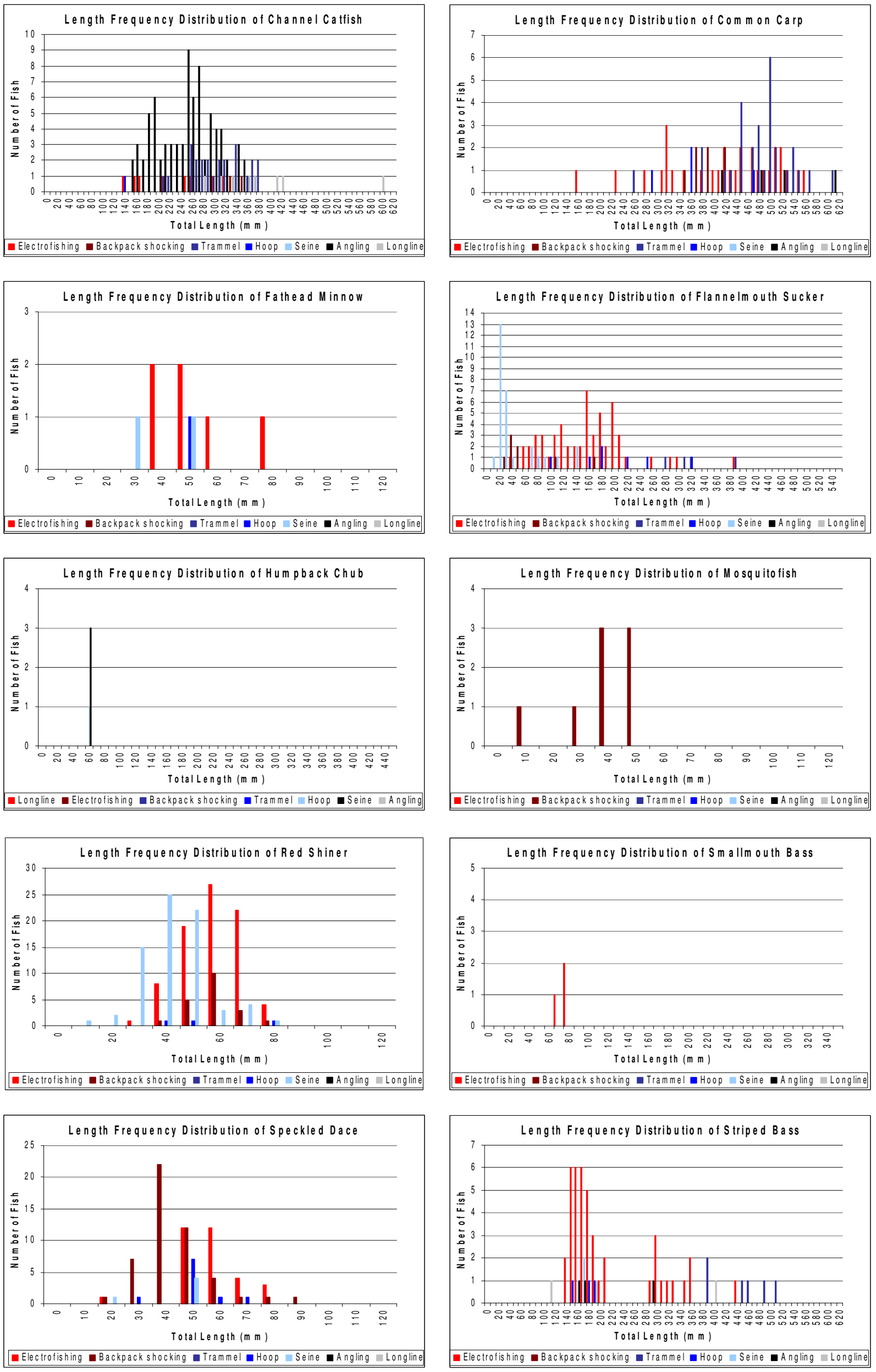

Figure 2. Length frequency distributions of fish captured during the 2005 Diamond Creek to Pearce Ferry fish survey trip.

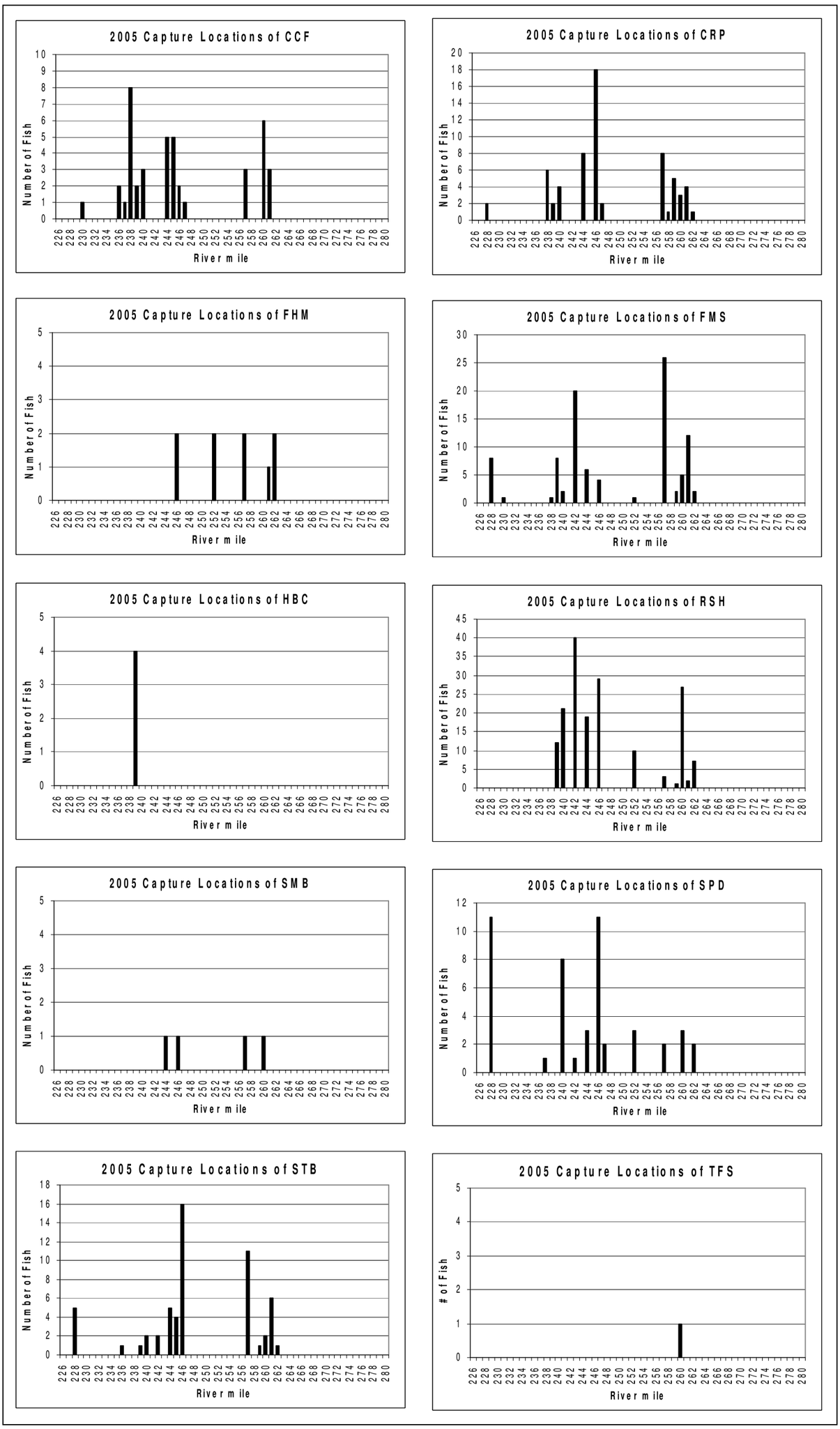

Figure 3. Longitudinal distribution of fish captured during the 2005 Diamond Creek to Pearce Ferry fish survey trip.

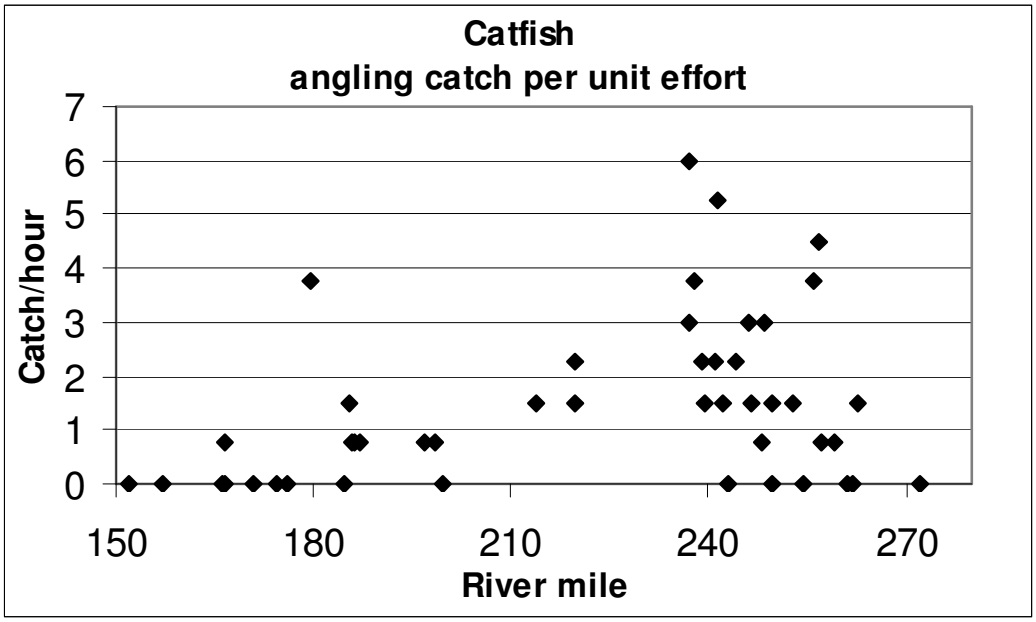

Figure 4. Angling catch rates of channel catfish captured during 2005 AGFD sampling.

TABLES

Table 1. 2005 Sampling Schedule for the Diamond Creek to Pearce Ferry Fish Monitoring

Logistic Reach	Start Mile	End Mile	Reach Length (miles)	Camp Mile	Sampling Separation Mile
1	225.8	235	9.2	229.1	229.0
2	235.1	246	10.9	239.6	240.2
3	246.1	259	12.9	246.4	249.1
3	246.1	259	12.9	246.4	249.1
4	259.1	265	5.9	260.2	262.8
4	259.1	265	5.9	260.2	262.8
6		Not sampled		277.0	

Table 2. 2004–05 Diamond Creek to Pearce Ferry Sampling Effort Summary

Reach	2004 Number of Samples					2005 Number of Samples						
	EF	ANG	TN	HN	SEN	EF	ANG	TN	HN	LL	SEN	BEF
11 (RM 226–236)	19	NA	0	0	0	22	3	5	0	0	0	0
12 (RM 236.1–256)	44	NA	22	63	0	98	19	30	108	33	9	0
13 (RM 256.1–276)	67	NA	41	117	28	50	7	20	75	20	1	0
Tributaries	0	NA	0	0	0	0	0	0	0	0	0	9
Total	**130**	**0**	**63**	**180**	**28**	**170**	**29**	**55**	**183**	**53**	**10**	**9**

EF = electrofishing, ANG = angling, TN = trammel nets, HN = hoop nets, LL = long lines, SEN = seines, BEF = backpack electrofishing

Table 3. Summary of Fish Captures from Diamond Creek to Pearce Ferry in 2004–05

2004	BHS	CCF	CRP	FHM	FMS	HBC	MOS	RBT	RSH	SMB	SPD	STB	TFS
Electrofishing	0	1	16	0	22	0	0	1	65	0	4	0	0
Angling	0	59	0	0	0	0	0	0	0	0	0	0	0
Trammel netting	0	12	12	0	3	0	0	0	0	0	0	0	0
Hoop netting	0	3	4	0	4	0	0	0	5	0	6	0	0
Seining	3	1	1	15	53	0	80	0	17	0	108	0	0
Total	**3**	**76**	**33**	**15**	**82**	**0**	**80**	**1**	**87**	**0**	**118**	**0**	**0**
2005	**BHS**	**CCF**	**CRP**	**FHM**	**FMS**	**HBC**	**MOS**	**RBT**	**RSH**	**SMB**	**SPD**	**STB**	**TFS**
Electrofishing	0	8	30	6	56	0	0	0	81	3	32	42	0
Angling	0	80	5	0	0	0	0	0	0	0	0	3	0
Trammel netting	0	24	30	0	4	0	0	0	0	0	0	6	1
Hoop netting	0	1	4	1	9	1	0	0	3	1	10	3	0
Long lines	0	9	0	0	0	0	0	0	0	0	0	3	0
Seining	0	0	0	2	29	3	0	0	87	0	5	3	0
Backpack electrofishing	0	4	13	0	8	0	8	0	20	0	49	0	0
Total	**0**	**126**	**82**	**9**	**106**	**4**	**8**	**0**	**191**	**4**	**96**	**60**	**1**

BHS = bluehead sucker, CCF = channel catfish, CRP = common carp, FHM = fathead minnow, FMS = flannelmouth sucker, HBC = humpback chub, MOS = mosquitofish, RBT = rainbow trout, RSH = red shiner, SMB = smallmouth bass, SPD = speckled dace, STB = striped bass, and TFS = threadfin shad

Table 4. Catch Rate Coefficient of Variation Summary by Gear Type for Species Captured during June 2005 Diamond Creek to Pearce Ferry Fish Survey Trip

Gear Type	Coefficient of Variation										
	CCF	CRP	FHM	FMS	HBC	MOS	RSH	SMB	SPD	STB	TFS
Electrofishing	0.45	0.19	0.40	0.24	–	–	0.14	0.57	0.19	0.16	–
Angling	0.18	0.41	–	–	–	–	–	–	–	0.55	–
Trammel net	0.28	0.34	–	0.49	–	–	–	–	–	0.70	1.0
Hoop net	1.0	0.50	1.0	0.33	1.0	–	0.75	1.0	0.34	0.57	–
Seine	–	–	1.0	0.64	0.77	–	0.39	–	0.50	0.66	–
Long line	0.34	NA	NA	NA	–	–	NA	NA	NA	0.90	NA
Backpack shocker	0.51	0.53	–	1.0	–	1.0	0.54	–	0.72	–	–

CCF = channel catfish, CRP = common carp, FHM = fathead minnow, FMS = flannelmouth sucker, HBC = humpback chub, MOS = mosquitofish, RSH = red shiner, SMB = smallmouth bass, SPD = speckled dace, STB = striped bass, and TFS = threadfin shad